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(56) Documents cited
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(58) Field of search
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INT CL⁴ G02B

(54) **High Temperature optical cables**

(57) Many applications of optical cables require them to be high temperature stable. To achieve this, the optical fibre has a layer of a polyimide, such as poly – [N,N' – (4,4' – oxydiphenylene) – pyro–mellitimide], over the fibre. This layer is itself covered by another layer, which can be an on-line coating or a buffering layer.

Components as described above can be assembled into optical cables.

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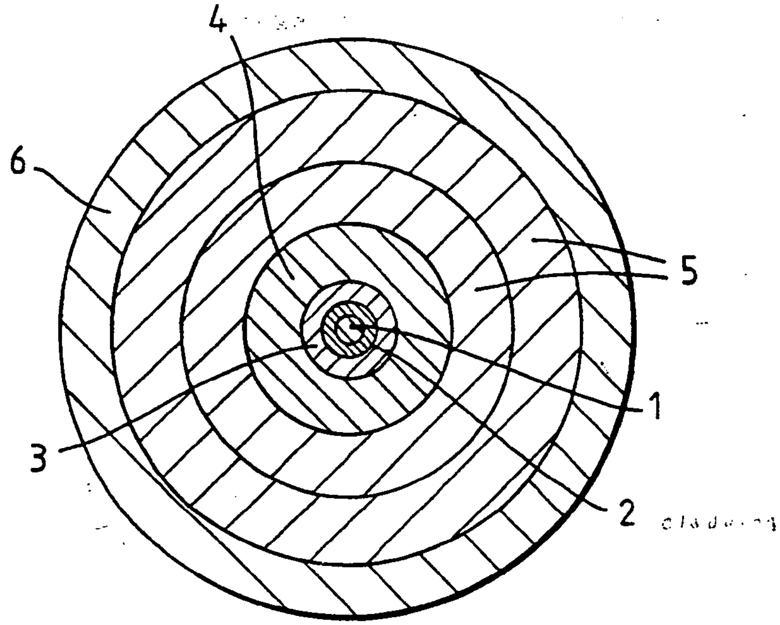

Fig.1.

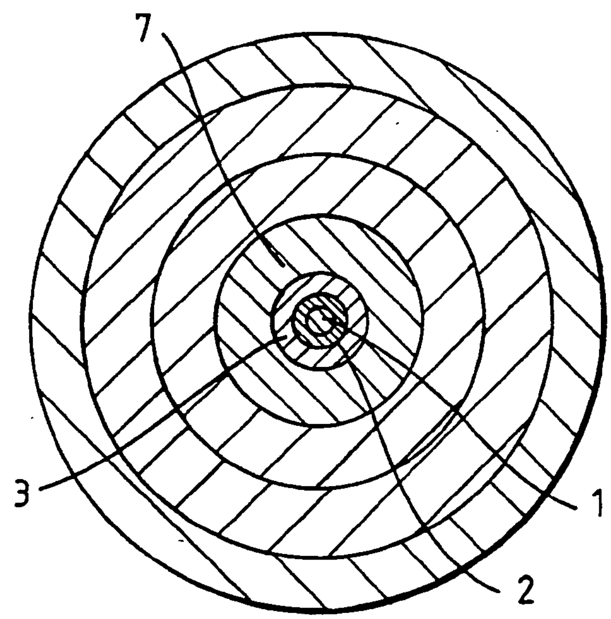

Fig.2.

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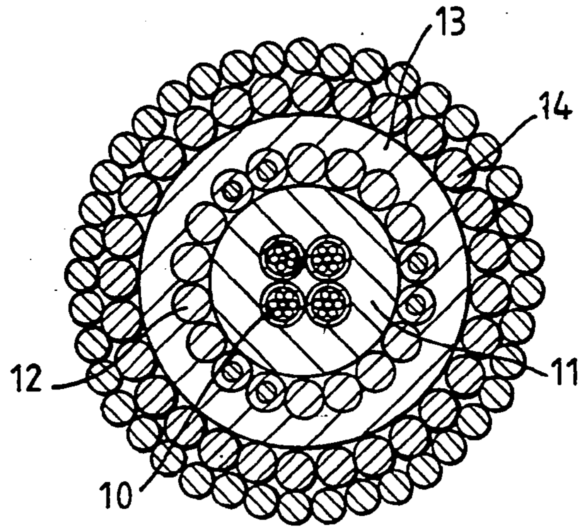

Fig.3.

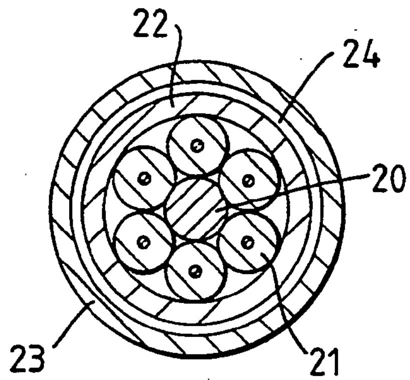

Fig.4.

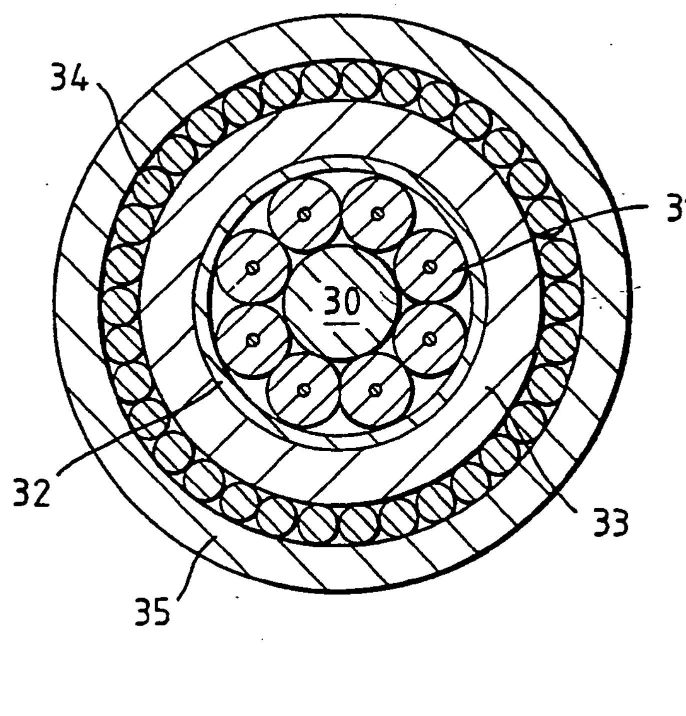

Fig.5.

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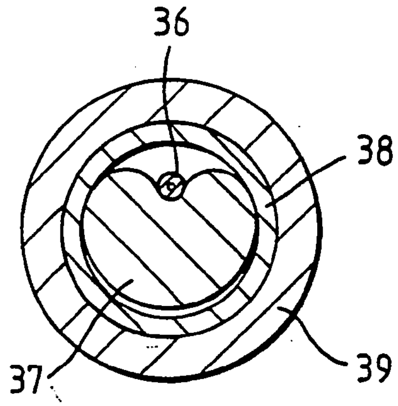

Fig.6.

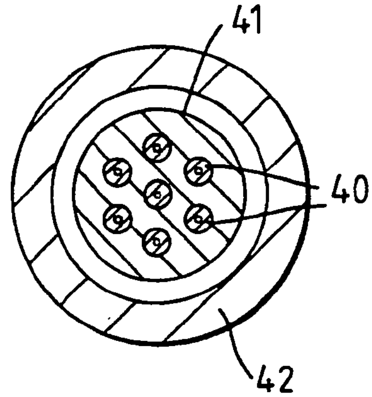

Fig.7.

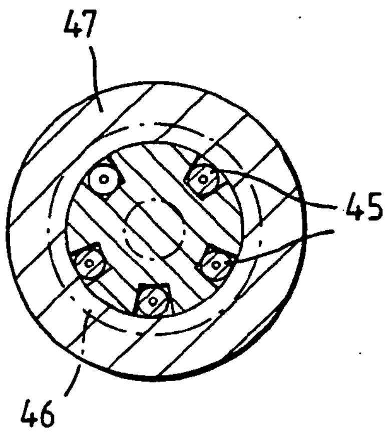

Fig.8.

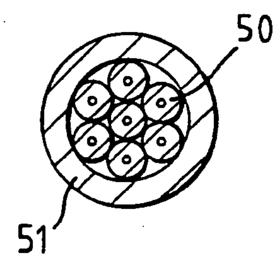

Fig.9.

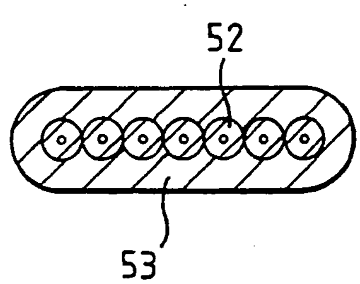

Fig.10.

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HIGH TEMPERATURE OPTICAL CABLES

This invention relates to optical fibre cables and components therefor, especially where stability at high temperatures is required. Such cables have both civil and military area applications.

Conventional on line coating materials such as silicone resin or urethane/epoxy acrylates degrade at elevated tempeatures, causing optical losses in the fibre. Other polymeric materials used for secondary coating or sheathing, such as Nylon or polystyrene decompose at above 250°C in air, and even highly stable PTFE decomposes at about 315°C. With conventional stranded cable construction, high temperature annealing causes unacceptably high attenuation increments.

Our Patent No. 2139779B (M.K.R. Vyas 8) described the use of polyimide tape core wrap on an optical fibre, which substantially improved the thermal stability of the cable core. An object of this invention is to extend the underlying principles set out in this Patent in a useful way.

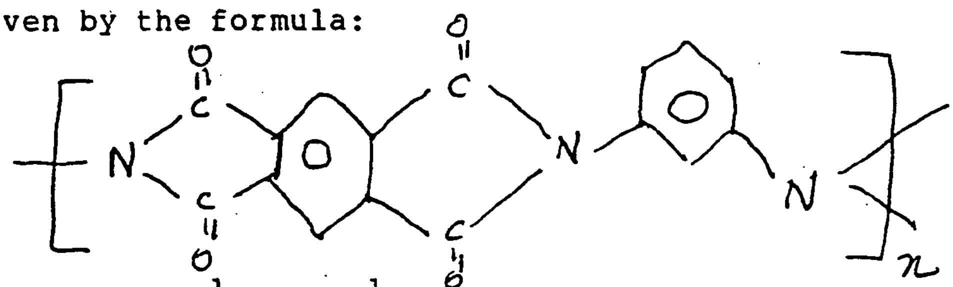
According to the invention, there is provided a cable component suitable for assembly into an optical fibre cable, which includes an optical fibre having a polyimide coating overlying the fibre and a further coating overlying the polyimide.

According to the invention, there is also provided an optical fibre cable which includes at least one optical fibre assembled within a sheath, the or each

said fibre having a polyimide coating overlying the fibre and a further coating overlying the polyimide.

Such a use of an on-line polyimide-based coating on a glass fibre provides an excellent starting cable component. It not only improves fibre strength, but also improves subsequent handleability of the fibre. Further, proof testing can be carried out on-line or off-line and to high levels, e.g. 1% - 1.5%.

One polyimide which can advantageously be used is given by the formula:



i.e. poly - [N,N^1 - ($4,4^1$ - oxydisphenylene) - pyromellitimide].

Other advantages of using polyimide in optical cables are:

(i) Higher operating temperature, as the theoretical T_g of polyimide is around 270^{o}C, whereas that of epoxy is 130^{o}C. Further, polyimide can withstand continuous operating temperatures of around 170^{o}C.

(ii) Polyimide has a relatively low coefficient of thermal expansion, i.e. 1-2 x $10^{-5}/^{o}$C.

(iii) Good chemical and radiation resistances.

(iv) Modest water absorption, e.g. 0.5% by weight.

(v) High tensile strength and tear resistance.

(vi) Good abrasion resistance.

The structures described all use polyimide primary coated fibres, with an additional and different, layer as a base unit. Thus for tight cable constructions, buffering may be needed as polyimide is reasonably hard. Hence softer high temperature stable grades of polymeric or silicone resins are use for

on-line or off-line buffering to minimise bend losses. The cable structures described below use one of the following as a base unit:

(i) Polyimide-coated fibre plus a softer polymer extrusion coating.

(ii) Polyimide-coated fibre plus high temperature stable silicone buffer.

(iii) Fibre (ii) plus high temperature stable polymer coating.

(iv) Either (i) or (ii) on their own in loose cable constructions.

Examples of high temperature polymers for secondary coatings or external sheaths and reinforcements indicate:

(i) Poly-ether-ether-ketone (PEEK), e.g. Victrex (Trade Mark) from ICI, or poly-ether-ketone (PEK).

(ii) Polyetherimide, e.g. Ultem (Trade Mark) from General Electric Plastics.

(iii) Polyether sulphone (PES), from ICI.

(iv) Polyimide, e.g. Kapton (Trade Mark) or Liquid H Polyimide from Du Pont or Upilex (Trade Mark) from UBE, Japan.

(v) Tefzel - a copolymer of ethylene and tetrafluroethylene (Trade Mark) from ICI.

(vi) Liquid crystal polymer (LCP), e.g. from Celanese.

Various embodiments of the invention will now be described with reference to the accompanying drawings.

Fig. 1 is a single fibre cable in which the core 1 and its cladding have a reference surface 2 to which an on-line coating 3 of polyimide is applied, which is buffered with a coating 4 of a softer grade of high temperature stable silicone or acrylate resins or of polyimide resin, to minimise bend losses. Buffered package size can vary from 300μm O.D. to 500μm O.D. This buffered fibre is then reinforced with coatings 5 of Kevlar (Trade Mark) 29 or 49, laid parallel or

contra-helical, and finally sheathed by an outer sheath 6. Alternatively the Kevlar reinforced unit is in a mechanical register by a polyimide tape, e.g. Upilex or Kapton, 2.5 to 3mm wide and then sheathed with a suitable high temperature stable sheath material.

In Fig. 2, the polyimide-coated fibre is secondary coated with a coating 7 of, for instance, PEEK, Ultem or PES. PES provides a radiation-resistant secondary coating. Suitable extrusion-coated package sizes are 0.5mm O.D., 0.85mm O.D. and 1.00mm O.D. Again, final reinforcements are as for Fig. 1, and such a unit can be made to 1.0 to 2.0mm O.D. depending on the amount of reinforcement needed. Such cables are used in various military, air and naval deployable cable applications.

Basic units such as shown in Figs. 1 or 2 can be incorporated in a composite cable structure, Fig. 3, e.g. for use as a sonar buoy tow cable. Here we have a central power quad 10 with its own sheath 11 about which we have a ring 12 of twelve fibre units and six electrical units, the latter being shown as rings with dots in the middle. This ring has its own sheath 13 over which is an armour layer 14 formed of high strength galvanised steel wire, torque balanced.

Fig. 4 is a submarine cable with a central strength member, e.g. of Kevlar, 20, surrounded by six on line coated or buffered fibres 21. These are in a sheath 22, e.g. of PEEK or Ultem, and provide a central core inserted into a copper C-section 23, possibly with a filling 24 of high temperature grease. This C-section 23 can itself be within an outer sheath, possibly also with armouring.

Fig. 5 is a tatical field-deployable cable. It has a central strength member 30, which is buffered, about which there are eight optical fibre cable components 31, each of which is on-line coated or buffered. These are overlaid in turn by a tape whip 32,

an inner sheath 33, a multi-wire reinforcement 34 and an outer sheath 35. Here the basic fibre units are either secondary/polyimide coated fibre, or buffered polyimide/silicone resin/secondary coated fibre. the central strength member 30 is of glass reinforced LCP or GRP, and the tape whip which maintains the fibre units in mechanical register is a polyimide tape, such as Kapton or Upilex. The sheathing materials can be polyetheretherketone, polyetherimide or polyetherketone or liquid crystal polymer (LCP).

A cable component such as described with reference to Figs. 1 or 2 can be used as part of an aerial cable, e.g. of the Fibrespan (Trade Mark) type, see Fig. 6. Here a cable component 36 which is buffered or on-line coated, is supported in a recess of a solid member 37, which as shown is roughly heart shaped. This is surrounded by tape 38 and a sheath 39. The member 37 may be of metal, so as to act as an electrical conductor in addition to supporting the optical fibre cable component.

Cable components such as described with reference to Figs. 1 and 2 can also be used in cables of the loose tube type, see Fig. 7. This we see as a set of polyimide coated fibres 40, seven as shown, either buffered or coated, loosely located in a tube 41. The interlayer tape for these fibres is a polyimide. The tube is glass reinforced LCP, and also has a high temperature stable thixotropic filler. The whole is enclosed by a high temperature stable sheath 42, e.g. of polyetheretherketone or polyetherketone.

Another loose tube arrangement is shown in Fig. 8. Here we have a central strength member 44 of K49 glass or GRP, which has a number of recesses, five as shown, in its outer surface in each of which there is a cable component 45 of the type shown in Fig. 1 or 2. These are held in place by a layer 46 of polyimide tape,

which is itself overlaid by a high temperature stable sheath 47.

Another application for cables using cable components such as shown in Figs. 1 and 2 is shown in Fig. 9, which is a high capacity miniature subscriber/local area network cable. Here we see a number, seven as shown, of fibres 50, on line coated or buffered, within a simple sheath 51. Here the fibres are fed in parallel and oversheathed with high temperature stable polymer to 1.5 to 2.0mm outside diameter cable.

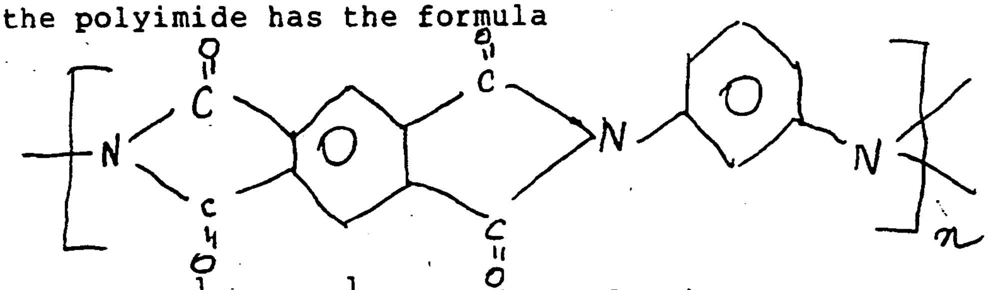
Yet another application of the cable components is shown in Fig. 10, which is an "under-carpet" or oil rig communications cable. Here polyimide coated or buffered fibres such as 52 are contained inside a flat high temperature sheath.

Reference is hereby directed to our copending Application No. (Serial No.) (M.J. Herman 3), filed simultaneously with the present Application, which relates to ruggedised optical fibres for use in extreme temperature, particularly high temperature, environments and methods of making them. The fibres may be primary coated with polyimide and has a further layer overlying the polyimide.

CLAIMS:

1. A cable component suitable for assembly into an optical fibre cable, which includes an optical fibre having a polyimide coating overlying the fibre and a further coating overlying the polyimide.

2. A cable component as claimed in claim 1, in which the polyimide has the formula



i.e. poly - [N,N^1 - (4,4^1 - oxydiphenylene) - pyromellitimide].

3. A cable component as claimed in claim 1 or 2, in which the further coating is poly-ether-ether ketone.

4. A cable component as claimed in claim 1 or 2, in which the further coating is poly-ether ketone.

5. A cable component as claimed in claim 1 or 2, in which the further coating is polyetherimide.

6. A cable component as claimed in claim 1 or 2, in which the further coating is polyether sulphone.

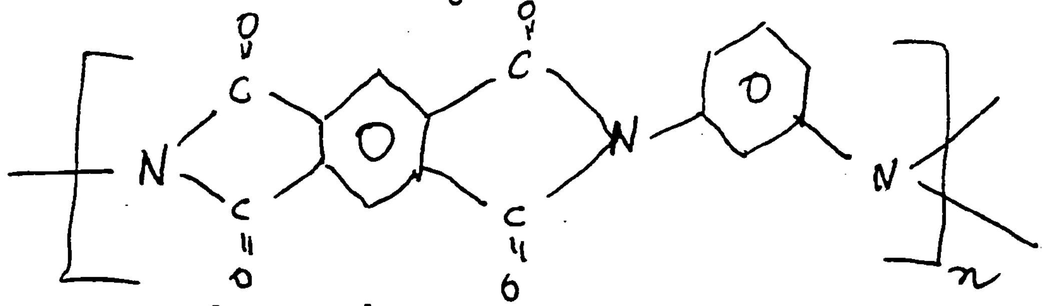
7. A cable component as claimed in claim 1 or 2, in which the further coating is also polyimide.

8. A cable component as claimed in claim 1 or 2, in which the further coating is a copolymer of ethylene and tetrafluoroethylene.

9. A cable component as claimed in claim 1 or 2, in which the further coating is a liquid crystal polymer.

10. An optical fibre cable which includes at least one optical fibre assembled within a sheath, the or each said fibre having a polyimide coating overlying the fibre and a further coating overlying the polyimide.

11. An optical fibre cable as claimed in claim 10, in which the polyimide has the formula:



i.e. poly -[N,N^1 - (4,4^1-oxydiphenylene) - pyromellitimide].

12. A cable as claimed in claim 10 or 11, in which the further coating is poly-ether-ether ketone.

13. A cable as claimed in claim 10 or 11, in which the further coating is poly-ether ketone.

14. A cable as claimed in claim 10 or 11, in which the further coating is polyetherether.

15. A cable as claimed in claim 10 or 11, in which the further coating is polyimide sulphone.

16. A cable as claimed in claim 10 or 11, in which the further coating is also polyimide.

17. A cable as claimed in claim 10 or 11, in which the further coating is a copolymer of ethylene and tetrafluoroethylene.

18. A cable as claimed in claim 10 or 11, in which the further coating is a liquid crystal polymer.

19. A cable as claimed in claim 12, 14, or 15, in which the further coating is overlaid by a coating of Kevlar (Registered Trade Mark) laid parallel or contra helical, there being an outer sheath overlaying the further coating.

20. An optical fibre cable, which includes a central power quad of metallic conductors for the conveyence of power, a sheath overlying said central quad, a ring of conductors overlying said sheath, some of which conductors are electrical and some of which are optical cable components each as claimed in any one of claims 1 to 9, a sheath overlying said ring of conductors, and an armour layer which overlies the last named sheath.

21. An optical fibre cable, which includes a central strength member of a synthetic material, a ring of optical cable components each as claimed in any one of claims 1 to 9 overlying the strength member, a sheath overlying the cable components, a C-section of copper overlying the sheath and caused to completely enclose that sheath, and a further sheath overlying the C-section.

22. A cable as claimed in claim 21, and which includes a filling of a high temperature grease between the first-named sheath and the C-section.

23. A cable as claimed in claim 21 or 22, in which the central strength member is of Kevlar (Trade Mark) and the first named sheath is of polyetheretherketone, polyetherketone or of polyetherimide.

24. An optical fibre cable which includes a central strength member whose outer surface is buffered, a number of optical cable components each as claimed in any one of claims 1 to 9 overlaying the strength member, a tape whip over the cable components to maintain them in mechanical register, a first sheath which overlays the tape whip, a reinforcement layer overlaying the first sheath, and a second sheath which overlays the reinforcement layer.

25. A cable as claimed in claim 24, in which the strength member is glass reinforced LCP or GRP, the tape whip is a polyimide tape, and the sheaths are of polyetheretherketone, polyetherketone or polyetherimide or LCP.

26. An optical fibre cable, which includes a solid core member whose cross section is roughly heart shaped, an optical cable component as claimed in any one of claims 1 to 9 located in the trough formed by the re-entrant portion of the heart shaped core member, a tape wrap overlaying the core member and the optical cable component, and an outer sheath overlaying the tape wrap.

27. A cable as claimed in claim 26, in which the core member is metallic, so that it can be used as an electrical conductor.

28. An optical fibre cable of the loose tube type which includes one or more cable components each as claimed in any one of claims 1 to 9 loosely located in an outer tube, there being a high temperature stable thixotropic filter inside the tube.

29. An optical cable of the loose tube type which includes a central generally cylindrical strength member having a number of longitudinally extending grooves in its outer surface, optical cable components each as claimed in any one of claims 1 to 9 and each located in one of said grooves, a tape wrap overlaying the grooves and the cable components, and a sheath overlying the tape wrap.

30. An optical fibre cable which includes a number of optical cable components each as claimed in any one of claims 1 to 9, all located in a close-fitting sheath of a high temperature stable material.

31. An optical cable component, substantially as described with reference to Fig. 1 or 2 of the accompanying drawings.

32. An optical fibre cable, substantially as described with reference to any one of Figs. 1 to 10 of the accompanying drawings.